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मानक

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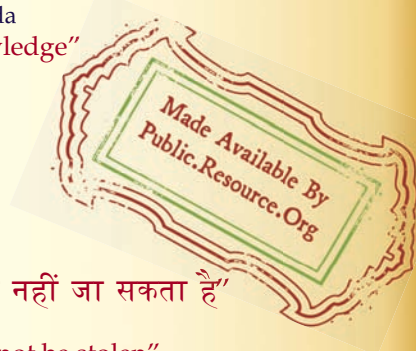
IS 1500 (2005): Method for Brinell Hardness Test for
Metallic Materials [MTD 3: Mechanical Testing of Metals]



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“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक
धातुओं की ब्रिनेल कठोरता परीक्षण करने की पद्धति
(तीसरा पुनरीक्षण)

Indian Standard
METHOD FOR BRINELL HARDNESS TEST FOR
METALLIC MATERIALS
(*Third Revision*)

ICS 77.040.10

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NATIONAL FOREWORD

This Indian Standard (Third Revision) which is identical with ISO 6506-1 : 1999 'Metallic materials — Brinell hardness test — Part 1 : Test method' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendations of the Mechanical Testing of Metals Sectional Committee and approval of the Metallurgical Engineering Division Council.

This standard was originally published in 1959 and subsequently revised in 1968 and 1983. This revision of the standard has been taken up to align it with ISO 6506-1 : 1999 by adoption under dual numbering system.

In this revision, the use of steel balls have been discontinued in favour of carbide balls, to bring it in line with the International practice.

In the adopted standard, some terminology and conventions are, however, not identical to those used in Indian Standards. Attention is especially drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be as read as 'Indian Standard'.
- b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to the following International Standard for which Indian Standard also exists. The corresponding Indian Standard which is to be substituted in its place is listed below along with its degree of equivalence for the edition indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
ISO 6506-2 : 1999 Metallic materials — Brinell hardness test — Part 2 : Verification and calibration of testing machines	IS 2281 : 2005 Method for verification of Brinell hardness testing machines (<i>third revision</i>)	Identical

The concerned Technical Committee has reviewed the provisions of the following International Standard referred in this adopted standard and has decided that this is acceptable for use in conjunction with this standard:

<i>International Standard</i>	<i>Title</i>
ISO 4498-1	Sintered metal materials, excluding hardmetals — Determination of apparent hardness — Part 1: Materials of essentially uniform section hardness

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard
**METHOD FOR BRINELL HARDNESS TEST FOR
METALLIC MATERIALS**
(Third Revision)

1 Scope

This part of ISO 6506 specifies the method for the Brinell hardness test for metallic materials and is applicable up to the limit of 650 HBW.

For specific materials and/or products, particular International Standards exist (i.e. ISO 4498-1).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 6506. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 6506 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 4498-1, *Sintered metal materials, excluding hardmetals — Determination of apparent hardness — Part 1: Materials of essentially uniform section hardness.*

ISO 6506-2:1999, *Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines.*

3 Principles

An indenter (hardmetal ball with diameter D) is forced into the surface of a test piece and the diameter of the indentation d left in the surface after removal of the force F is measured.

The Brinell hardness is proportional to the quotient obtained by dividing the test force by the curved surface area of the indentation. The indentation is assumed to be spherical with a radius corresponding to half of the diameter of the ball.

4 Symbols and designations

See Figure 1 and Table 1.

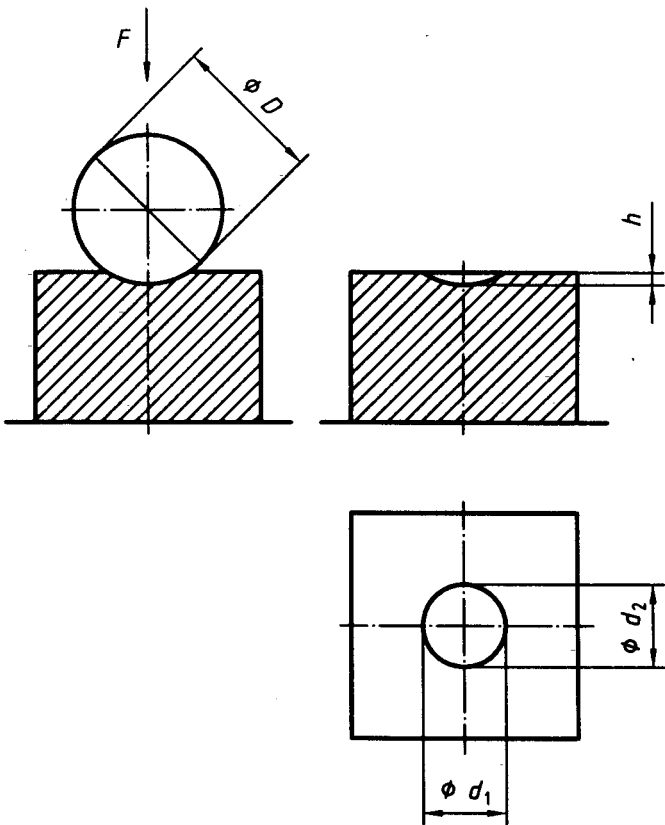


Figure 1 — Principle of test

Table 1 — Symbols and designations

Symbol	Designation	Unit
D	Diameter of the ball	mm
F	Test force	N
d	Mean diameter of the indentation $\left(d = \frac{d_1 + d_2}{2} \right)$	mm
d_1, d_2	Indentation diameters measured at 90°	mm
h	Depth of indentation $= \frac{D - \sqrt{D^2 - d^2}}{2}$	mm
HBW	Brinell hardness $= \text{Constant} \times \frac{\text{Test force}}{\text{Surface area of indentation}}$ $= 0,102 \times \frac{2F}{\pi D \left(D - \sqrt{D^2 - d^2} \right)}$	
$0,102 \times F/D^2$	force-diameter ratio	N/mm ²

NOTE

Constant = $\frac{1}{g_n} = \frac{1}{9,806\,65} = 0,102$

g_n = acceleration due to gravity

4.1 The Brinell hardness is denoted by HBW.

NOTE In former standards, in cases when a steel ball had been used, the Brinell hardness was denoted by HB or HBS.

4.2 The letters HBW are preceded by the hardness value and supplemented by an index indicating the test conditions in the order:

- a) the diameter of the ball, in millimetres;
- b) a figure representing the test force (see Table 2);
- c) the duration of application of test force, in seconds, if different from the specified time (see 7.5).

EXAMPLE 1 350 HBW 5/750 = Brinell hardness of 350 determined with a ball of 5 mm diameter and with a test force of 7,355 kN applied for 10 s to 15 s.

EXAMPLE 2 600 HBW 1/30/20 = Brinell hardness of 600 determined with a ball of 1 mm diameter and with a test force of 294,2 N applied for 20 s.

5 Testing machine

5.1 Testing machine, capable of applying a predetermined test force or forces within the range of 9,807 N to 29,42 kN in accordance with ISO 6506-2.

5.2 Indenter, a polished hardmetal ball, as specified in ISO 6506-2.

5.3 Measuring device, as specified in ISO 6506-2.

NOTE A suggested procedure for periodic checks by the user is given in annex A.

6 Test piece

6.1 The test shall be carried out on a surface which is smooth and even, free from oxide scale, foreign matter and, in particular, free from lubricants. The test piece shall have a surface finish that will allow an accurate measurement of the diameter of the indentation.

6.2 Preparation shall be carried out in such a way that any alteration of the surface, for example due to heat- or cold-working, is minimized.

6.3 The thickness of the test piece shall be at least eight times the depth of indentation. Values for the minimum thickness of the test piece in relation to the mean diameter of indentation are given in annex B.

Visible deformation at the back of the test piece can indicate that the test piece is too thin.

7 Procedure

7.1 In general, the test is to be carried out at ambient temperature within the limits of 10 °C to 35 °C. Tests carried out under controlled conditions shall be made at a temperature of (23 ± 5) °C.

7.2 The test forces given in Table 2 shall be used.

7.3 The test force shall be chosen so that the diameter of the indentation d lies between the values $0,24 D$ and $0,6 D$.

The force-diameter ratio $(0,102 \times F/D^2)$ shall be chosen according to the material and the hardness test as indicated in Table 3.

In order to test the largest representative area of the test piece, the diameter of the testing ball shall be chosen to be as large as possible.

When the thickness of the test piece permits, a 10 mm diameter ball is preferred.

7.4 The test piece shall be placed on a rigid support. The contact surfaces shall be clean and free from foreign matter (scale, oil, dirt, etc). It is important that the test piece lie firmly on the support so that displacement cannot occur during the test.

7.5 Bring the indenter into contact with the test surface and apply the test force in a direction perpendicular to the surface, without shock, vibration or overrun, until the applied force attains the specified value. The time from the initial application of force to the time the full test force is reached shall not be less than 2 s nor greater than 8 s. Maintain the test force for 10 s to 15 s. For certain materials, where a longer dwell time is required; this time shall be applied with a tolerance of ± 2 s.

7.6 Throughout the test, the testing machine shall be protected from significant shock or vibration which can influence the test result.

7.7 The distance from the edge of the test piece to the centre of each indentation shall be a minimum of two and a half times the mean indentation diameter.

The distance between the centres of two adjacent indentations shall be at least three times the mean indentation diameter.

Table 2 — Test forces for the different testing conditions

Hardness symbol	Ball diameter <i>D</i> mm	Force-diameter ratio $0,102 \times F/D^2$ N/mm ²	Nominal value of test force <i>F</i> N
HBW 10/3 000	10	30	29 420
HBW 10/1 500	10	15	14 710
HBW 10/1 000	10	10	9 807
HBW 10/500	10	5	4 903
HBW 10/250	10	2,5	2 452
HBW 10/100	10	1	980,7
HBW 5/750	5	30	7 355
HBW 5/250	5	10	2 452
HBW 5/125	5	5	1 226
HBW 5/62,5	5	2,5	612,9
HBW 5/25	5	1	245,2
HBW 2,5/187,5	2,5	30	1 839
HBW 2,5/62,5	2,5	10	612,9
HBW 2,5/31,25	2,5	5	306,5
HBW 2,5/15,625	2,5	2,5	153,2
HBW 2,5/6,25	2,5	1	61,29
HBW 1/30	1	30	294,2
HBW 1/10	1	10	98,07
HBW 1/5	1	5	49,03
HBW 1/2,5	1	2,5	24,52
HBW 1/1	1	1	9,807

Table 3 — The force-diameter ratio for different metallic materials

Material	Brinell hardness HBW	Force-diameter ratio $0,102 \times F/D^2$ N/mm ²
Steel - Nickel alloys Titanium alloys		30
Cast iron ^a	< 140 ≥ 140	10 30
Copper and copper alloys	< 35	5
	35 to 200	10
	> 200	30
Light metals and their alloys	< 35	2,5
		5
	35 to 80	10
		15
	> 80	10
		15
Lead, tin		1
Sintered metal	See ISO 4498-1	

^a For the testing of cast iron the nominal diameter of the ball shall be 2,5 mm, 5 mm or 10 mm.

7.8 Measure the diameter of each indentation in two directions perpendicular to each other. The arithmetic mean of the two readings shall be taken for the calculation of the Brinell hardness.

NOTE For some testing machines, the following should be used:

- the average of a greater number of symmetrically placed measurements;
- an assessment of the projected indentation area into the material surface.

7.9 Table C.1 (see annex C) contains calculation tables which shall be used to determine the Brinell hardness for tests on flat surfaces.

8 Uncertainty of the results

The uncertainty of results is dependent on various parameters which may be separated into two categories:

- a) parameters dependent on the Brinell hardness testing machine (including the uncertainty of the verification of the testing machine and on the calibration of the reference blocks);
- b) parameters dependent on the application of the test method (variation of the operating conditions).

NOTE A complete evaluation of the uncertainty should be carried out according to the *Guide to the Expression of Uncertainty in Measurement*^[1]. Indicative values of the extended uncertainty at a confidence level of 95 % can be taken to be equal to the maximum permissible error given in Table 2 of ISO 6506-2:1999.

9 Test report

The test report shall include the following information:

- a) a reference to this International Standard, i.e. ISO 6506-1;
- b) all details necessary for the complete identification of the test piece;
- c) the test temperature if it is not within the limits $(23 \pm 5) ^\circ\text{C}$;
- d) the result obtained;
- e) additional requirements outside the scope of this part of ISO 6506;
- f) details of any occurrence which may have affected the result.

NOTE 1 There is no general process of accurately converting Brinell hardness into other scales of hardness or into tensile strength. These conversions should therefore be avoided, unless a reliable basis for the conversion can be obtained by comparative tests.

NOTE 2 It should be noted that for anisotropic materials, for example those which have been heavily cold-worked, there may be a difference between the lengths of the two diameters of the indentation. The specification for the product may indicate limits for such differences.

Annex A

(informative)

Procedure for periodic checks of the testing machines by the user

The indirect verification procedure is too time consuming and costly for routine checking. The following procedure is recommended for this purpose.

Make at least one periodic check of the testing machine each day that it is used.

Before making the check, make at least two preliminary indentations to ensure that the test piece, indenter and anvil are seated correctly. The results of these preliminary indentations should be ignored.

Make at least one hardness indentation on a reference block with approximately the same hardness as the material being tested. If the difference between mean value of the hardness readings of the test material and the hardness of the reference block are within the limits given in Table 2 of ISO 6506-2:1999, the machine may be regarded as satisfactory. If not, an indirect verification should be performed.

Annex B
(normative)

Minimum thickness of the test piece in relation to the mean diameter of indentation

Table B.1 gives values for minimum thickness of the test piece in relation to the mean diameter of indentation.

Table B.1

Dimensions in millimetres

Mean diameter of the indentation <i>d</i>	Minimum thickness of the test piece			
	Diameter of the ball			
	<i>D</i> = 1	<i>D</i> = 2,5	<i>D</i> = 5	<i>D</i> = 10
0,2	0,08			
0,3	0,18			
0,4	0,33			
0,5	0,54			
0,6	0,8	0,29		
0,7		0,4		
0,8		0,53		
0,9		0,67		
1		0,83		
1,1		1,02		
1,2		1,23	0,58	
1,3		1,46	0,69	
1,4		1,72	0,8	
1,5		2	0,92	
1,6			1,05	
1,7			1,19	
1,8			1,34	
1,9			1,5	
2			1,67	
2,2			2,04	
2,4			2,46	1,17
2,6			2,92	1,38
2,8			3,43	1,6
3			4	1,84
3,2				2,1
3,4				2,38
3,6				2,68
3,8				3
4				3,34
4,2				3,7
4,4				4,08
4,6				4,48
4,8				4,91
5				5,36
5,2				5,83
5,4				6,33
5,6				6,86
5,8				7,42
6				8

Annex C (normative)

Determination of the Brinell hardness for testing on flat surfaces

The determination of the Brinell hardness for testing on flat surfaces is given in Table C.1.

Table C.1

Ball indenter <i>D</i> mm				Force-diameter ratio $0,102 \times F/D^2$					
				30	15	10	5	2,5	1
				Test force <i>F</i> N					
10	5	2,5	1	29 420 7 355 1 830 294,2	14 710 — — —	9 807 2 452 612,9 98,07	4 903 1 226 306,5 49,03	2 452 612,9 153,2 24,52	980,7 245,2 61,29 9,807
Mean diameter of the indentation <i>d</i> mm				Brinell hardness HBW					
2,40	1,200	0,600 0	0,240	653	327	218	109	54,5	21,8
2,41	1,205	0,602 4	0,241	648	324	216	108	54,0	21,6
2,42	1,210	0,605 0	0,242	643	321	214	107	53,5	21,4
2,43	1,215	0,607 5	0,243	637	319	212	106	53,1	21,2
2,44	1,220	0,610 0	0,244	632	316	211	105	52,7	21,1
2,45	1,225	0,612 5	0,245	627	313	209	104	52,2	20,9
2,46	1,230	0,615 0	0,246	621	311	207	104	51,8	20,7
2,47	1,235	0,617 5	0,247	616	308	205	103	51,4	20,5
2,48	1,240	0,620 0	0,248	611	306	204	102	50,9	20,4
2,49	1,245	0,622 5	0,249	606	303	202	101	50,5	20,2
2,50	1,250	0,625 0	0,250	601	301	200	100	50,1	20,0
2,51	1,255	0,627 5	0,251	597	298	199	99,4	49,7	19,9
2,52	1,260	0,630 0	0,252	592	296	197	98,6	49,3	19,7
2,53	1,265	0,632 5	0,253	587	294	196	97,8	48,9	19,6
2,54	1,270	0,635 0	0,254	582	291	194	97,1	48,5	19,4
2,55	1,275	0,637 5	0,255	578	289	193	96,3	48,1	19,3
2,56	1,280	0,640 0	0,256	573	287	191	95,5	47,8	19,1
2,57	1,285	0,642 5	0,257	569	284	190	94,8	47,4	19,0
2,58	1,290	0,645 0	0,258	564	282	188	94,0	47,0	18,8
2,59	1,295	0,647 5	0,259	560	280	187	93,3	46,6	18,7
2,60	1,300	0,650 0	0,260	555	278	185	92,6	46,3	18,5
2,61	1,305	0,652 5	0,261	551	276	184	91,8	45,9	18,4
2,62	1,310	0,655 0	0,262	547	273	182	91,1	45,6	18,2
2,63	1,315	0,657 5	0,263	543	271	181	90,4	45,2	18,1
2,64	1,320	0,660 0	0,264	538	269	179	89,7	44,9	17,9
2,65	1,325	0,662 5	0,265	534	267	178	89,0	44,5	17,8
2,66	1,330	0,665 0	0,266	530	265	177	88,4	44,2	17,7
2,67	1,335	0,667 5	0,267	526	263	175	87,7	43,8	17,5
2,68	1,340	0,670 0	0,268	522	261	174	87,0	43,5	17,4
2,69	1,345	0,672 5	0,269	518	259	173	86,4	43,2	17,3
2,70	1,350	0,675 0	0,270	514	257	171	85,7	42,9	17,1
2,71	1,355	0,677 5	0,271	510	255	170	85,1	42,5	17,0
2,72	1,360	0,680 0	0,272	507	253	169	84,4	42,2	16,9
2,73	1,365	0,682 5	0,273	503	251	168	83,8	41,9	16,8
2,74	1,370	0,685 0	0,274	499	250	166	83,2	41,6	16,6
2,75	1,375	0,687 5	0,275	495	248	165	82,6	41,3	16,5
2,76	1,380	0,690 0	0,276	492	246	164	81,9	41,0	16,4

Table C.1 (continued)

Ball indenter <i>D</i> mm				Force-diameter ratio $0,102 \times F/D^2$					
10	5	2,5	1	30	15	10	5	2,5	1
Mean diameter of the indentation <i>d</i> mm				Brinell hardness HBW					
2,77	1,385	0,692 5	0,277	488	244	163	81,3	40,7	16,3
2,78	1,390	0,695 0	0,278	485	242	162	80,8	40,4	16,2
2,79	1,395	0,697 5	0,279	481	240	160	80,2	40,1	16,0
2,80	1,400	0,700 0	0,280	477	239	159	79,6	39,8	15,9
2,81	1,405	0,702 5	0,281	474	237	158	79,0	39,5	15,8
2,82	1,410	0,705 0	0,282	471	235	157	78,4	39,2	15,7
2,83	1,415	0,707 5	0,283	467	234	156	77,9	38,9	15,6
2,84	1,420	0,710 0	0,284	464	232	155	77,3	38,7	15,5
2,85	1,425	0,712 5	0,285	461	230	154	76,8	38,4	15,4
2,86	1,430	0,715 0	0,286	457	229	152	76,2	38,1	15,2
2,87	1,435	0,717 5	0,287	454	227	151	75,7	37,8	15,1
2,88	1,440	0,720 0	0,288	451	225	150	75,1	37,6	15,0
2,89	1,445	0,722 5	0,289	448	224	149	74,6	37,3	14,9
2,90	1,450	0,725 0	0,290	444	222	148	74,1	37,0	14,8
2,91	1,455	0,727 5	0,291	441	221	147	73,6	36,8	14,7
2,92	1,460	0,730 0	0,292	438	219	146	73,0	36,5	14,6
2,93	1,465	0,732 5	0,293	435	218	145	72,5	36,3	14,5
2,94	1,470	0,735 0	0,294	432	216	144	72,0	36,0	14,4
2,95	1,475	0,737 5	0,295	429	215	143	71,5	35,8	14,3
2,96	1,480	0,740 0	0,296	426	213	142	71,0	35,5	14,2
2,97	1,485	0,742 5	0,297	423	212	141	70,5	35,3	14,1
2,98	1,490	0,745 0	0,298	420	210	140	70,1	35,0	14,0
2,99	1,495	0,747 5	0,299	417	209	139	69,6	34,8	13,9
3,00	1,500	0,750 0	0,300	415	207	138	69,1	34,6	13,8
3,01	1,505	0,752 5	0,301	412	206	137	68,6	34,3	13,7
3,02	1,510	0,755 0	0,302	409	205	136	68,2	34,1	13,6
3,03	1,515	0,757 5	0,303	406	203	135	67,7	33,9	13,5
3,04	1,520	0,760 0	0,304	404	202	135	67,3	33,6	13,5
3,05	1,525	0,762 5	0,305	401	200	134	66,8	33,4	13,4
3,06	1,530	0,765 0	0,306	398	199	133	66,4	33,2	13,3
3,07	1,535	0,767 5	0,307	395	198	132	65,9	33,0	13,2
3,08	1,540	0,770 0	0,308	393	196	131	65,5	32,7	13,1
3,09	1,545	0,772 5	0,309	390	195	130	65,0	32,5	13,0
3,10	1,550	0,775 0	0,310	388	194	129	64,6	32,3	12,9
3,11	1,555	0,777 5	0,311	385	193	128	64,2	32,1	12,8
3,12	1,560	0,780 0	0,312	383	191	128	63,8	31,9	12,8
3,13	1,565	0,782 5	0,313	380	190	127	63,3	31,7	12,7
3,14	1,570	0,787 0	0,314	378	189	126	62,9	31,5	12,6
3,15	1,575	0,787 5	0,315	375	188	125	62,5	31,3	12,5
3,16	1,580	0,790 0	0,316	373	186	124	62,1	31,1	12,4
3,17	1,585	0,792 5	0,317	370	185	123	61,7	30,9	12,3
3,18	1,590	0,795 0	0,318	368	184	123	61,3	30,7	12,3
3,19	1,595	0,797 5	0,319	366	183	122	60,9	30,5	12,2
3,20	1,600	0,800 0	0,320	363	182	121	60,5	30,3	12,1
3,21	1,605	0,802 5	0,321	361	180	120	60,1	30,1	12,0
3,22	1,610	0,805 0	0,322	359	179	120	59,8	29,9	12,0
3,23	1,615	0,807 5	0,323	356	178	119	59,4	29,7	11,9
3,24	1,620	0,810 0	0,324	354	177	118	59,0	29,5	11,8
3,25	1,625	0,812 5	0,325	352	176	117	58,6	29,3	11,7
3,26	1,630	0,815 0	0,326	350	175	117	58,3	29,1	11,7
3,27	1,635	0,817 5	0,327	347	174	116	57,9	29,0	11,6
3,28	1,640	0,820 0	0,328	345	173	115	57,5	28,8	11,5
3,29	1,645	0,822 5	0,329	343	172	114	57,2	28,6	11,4
3,30	1,650	0,825 0	0,330	341	170	114	56,8	28,4	11,4
3,31	1,655	0,827 5	0,331	339	169	113	56,5	28,2	11,3
3,32	1,660	0,830 0	0,332	337	168	112	56,1	28,1	11,2

Table C.1 (continued)

Ball indenter D mm				Force-diameter ratio $0,102 \times F/D^2$					
10	5	2,5	1	30	15	10	5	2,5	1
Mean diameter of the indentation d mm				Brinell hardness HBW					
3,33	1,665	0,832 5	0,333	335	167	112	55,8	27,9	11,2
3,34	1,670	0,835 0	0,334	333	166	111	55,4	27,7	11,1
3,35	1,675	0,837 5	0,335	331	165	110	55,1	27,5	11,0
3,36	1,680	0,840 0	0,336	329	164	110	54,8	27,4	11,0
3,37	1,685	0,842 5	0,337	326	163	109	54,4	27,2	10,9
3,38	1,690	0,845 0	0,338	325	162	108	54,1	27,0	10,8
3,39	1,695	0,847 5	0,339	323	161	108	53,8	26,9	10,8
3,40	1,700	0,850 0	0,340	321	160	107	53,4	26,7	10,7
3,41	1,705	0,852 5	0,341	319	159	106	53,1	26,6	10,6
3,42	1,710	0,855 0	0,342	317	158	106	52,8	26,4	10,6
3,43	1,715	0,857 5	0,343	315	157	105	52,5	26,2	10,5
3,44	1,720	0,860 0	0,344	313	156	104	52,2	26,1	10,4
3,45	1,725	0,862 5	0,345	311	156	104	51,8	25,9	10,4
3,46	1,730	0,865 0	0,346	309	155	103	51,5	25,8	10,3
3,47	1,735	0,867 5	0,347	307	154	102	51,2	25,6	10,2
3,48	1,740	0,870 0	0,348	306	153	102	50,9	25,5	10,2
3,49	1,745	0,872 5	0,349	304	152	101	50,6	25,3	10,1
3,50	1,750	0,875 0	0,350	302	151	101	50,3	25,2	10,1
3,51	1,755	0,877 5	0,351	300	150	100	50,0	25,0	10,0
3,52	1,760	0,880 0	0,352	298	149	99,5	49,7	24,9	9,95
3,53	1,765	0,882 5	0,353	297	148	98,9	49,4	24,7	9,89
3,54	1,770	0,885 0	0,354	295	147	98,3	49,2	24,6	9,83
3,55	1,775	0,887 5	0,355	293	147	97,7	48,9	24,4	9,77
3,56	1,780	0,890 0	0,356	292	146	97,2	48,6	24,3	9,72
3,57	1,785	0,892 5	0,357	290	145	96,6	48,3	24,2	9,66
3,58	1,790	0,895 0	0,358	288	144	96,1	48,0	24,0	9,61
3,59	1,795	0,897 5	0,359	286	143	95,5	47,7	23,9	9,55
3,60	1,800	0,900 0	0,360	285	142	95,0	47,5	23,7	9,50
3,61	1,805	0,902 5	0,361	283	142	94,4	47,2	23,6	9,44
3,62	1,810	0,905 0	0,362	282	141	93,9	46,9	23,5	9,39
3,63	1,815	0,907 5	0,363	280	140	93,3	46,7	23,3	9,33
3,64	1,820	0,910 0	0,364	278	139	92,8	46,4	23,2	9,28
3,65	1,825	0,912 5	0,365	277	138	92,3	46,1	23,1	9,23
3,66	1,830	0,915 0	0,366	275	138	91,8	45,9	22,9	9,18
3,67	1,835	0,917 5	0,367	274	137	91,2	45,6	22,8	9,12
3,68	1,840	0,920 0	0,368	272	136	90,7	45,4	22,7	9,07
3,69	1,845	0,922 5	0,369	271	135	90,2	45,1	22,6	9,02
3,70	1,850	0,925 0	0,370	269	135	89,7	44,9	22,4	8,97
3,71	1,855	0,927 5	0,371	268	134	89,2	44,6	22,3	8,92
3,72	1,860	0,930 0	0,372	266	133	88,7	44,4	22,2	8,87
3,73	1,865	0,932 5	0,373	265	132	88,2	44,1	22,1	8,82
3,74	1,870	0,935 0	0,374	263	132	87,7	43,9	21,9	8,77
3,75	1,875	0,937 5	0,375	262	131	87,2	43,6	21,8	8,72
3,76	1,880	0,940 0	0,376	260	130	86,8	43,4	21,7	8,68
3,77	1,885	0,942 5	0,377	259	129	86,3	43,1	21,6	8,63
3,78	1,890	0,945 0	0,378	257	129	85,8	42,9	21,5	8,58
3,79	1,895	0,947 5	0,379	256	128	85,3	42,7	21,3	8,53
3,80	1,900	0,950 0	0,380	255	127	84,9	42,4	21,2	8,49
3,81	1,905	0,952 5	0,381	253	127	84,4	42,2	21,1	8,44
3,82	1,910	0,955 0	0,382	252	126	83,9	42,0	21,0	8,39
3,83	1,915	0,957 5	0,383	250	125	83,5	41,7	20,9	8,35
3,84	1,920	0,960 0	0,384	249	125	83,0	41,5	20,8	8,30
3,85	1,925	0,962 5	0,385	248	124	82,6	41,3	20,6	8,26
3,86	1,930	0,965 0	0,386	246	123	82,1	41,1	20,5	8,21
3,87	1,935	0,967 5	0,387	245	123	81,7	40,9	20,4	8,17
3,88	1,940	0,970 0	0,388	244	122	81,3	40,6	20,3	8,13

Table C.1 (continued)

Ball indenter D mm				Force-diameter ratio $0,102 \times F/D^2$					
10	5	2,5	1	30	15	10	5	2,5	1
Mean diameter of the indentation d mm				Brinell hardness HBW					
3,89	1,945	0,972 5	0,389	242	121	80,8	40,4	20,2	8,08
3,90	1,950	0,975 0	0,390	241	121	80,4	40,2	20,1	8,04
3,91	1,955	0,977 5	0,391	240	120	80,0	40,0	20,0	8,00
3,92	1,960	0,980 0	0,392	239	119	79,5	39,8	19,9	7,95
3,93	1,965	0,982 5	0,393	237	119	79,1	39,6	19,8	7,91
3,94	1,970	0,985 0	0,394	236	118	78,7	39,4	19,7	7,87
3,95	1,975	0,987 5	0,395	235	117	78,3	39,1	19,6	7,83
3,96	1,980	0,990 0	0,396	234	117	77,9	38,9	19,5	7,79
3,97	1,985	0,992 5	0,397	232	116	77,5	38,7	19,4	7,75
3,98	1,990	0,995 0	0,398	231	116	77,1	38,5	19,3	7,71
3,99	1,995	0,997 5	0,399	230	115	76,7	38,3	19,2	7,67
4,00	2,000	1,000 0	0,400	229	114	76,3	38,1	19,1	7,63
4,01	2,005	1,002 5	0,401	228	114	75,9	37,9	19,0	7,59
4,02	2,010	1,005 0	0,402	226	113	75,5	37,7	18,9	7,55
4,03	2,015	1,007 5	0,403	225	113	75,1	37,5	18,8	7,51
4,04	2,020	1,010 0	0,404	224	112	74,7	37,3	18,7	7,47
4,05	2,025	1,012 5	0,405	223	111	74,3	37,1	18,6	7,43
4,06	2,030	1,015 0	0,406	222	111	73,9	37,0	18,5	7,39
4,07	2,035	1,017 5	0,407	221	110	73,5	36,8	18,4	7,35
4,08	2,040	1,020 0	0,408	219	110	73,2	36,6	18,3	7,32
4,09	2,045	1,022 5	0,409	218	109	72,8	36,4	18,2	7,28
4,10	2,050	1,025 0	0,410	217	109	72,4	36,2	18,1	7,24
4,11	2,055	1,027 5	0,411	216	108	72,0	36,0	18,0	7,20
4,12	2,060	1,030 0	0,412	215	108	71,7	35,8	17,9	7,17
4,13	2,065	1,032 5	0,413	214	107	71,3	35,7	17,8	7,13
4,14	2,070	1,035 0	0,414	213	106	71,0	35,5	17,7	7,10
4,15	2,075	1,037 5	0,415	212	106	70,6	35,3	17,6	7,06
4,16	2,080	1,040 0	0,416	211	105	70,2	35,1	17,6	7,02
4,17	2,085	1,042 5	0,417	210	105	69,9	34,9	17,5	6,99
4,18	2,090	1,045 0	0,418	209	104	69,5	34,8	17,4	6,95
4,19	2,095	1,047 5	0,419	208	104	69,2	34,6	17,3	6,92
4,20	2,100	1,050 0	0,420	207	103	68,8	34,4	17,2	6,88
4,21	2,105	1,052 5	0,421	205	103	68,5	34,2	17,1	6,85
4,22	2,110	1,055 0	0,422	204	102	68,2	34,1	17,0	6,82
4,23	2,115	1,057 5	0,423	203	102	67,8	33,9	17,0	6,78
4,24	2,120	1,060 0	0,424	202	101	67,5	33,7	16,9	6,75
4,25	2,125	1,062 5	0,425	201	101	67,1	33,6	16,8	6,71
4,26	2,130	1,065 0	0,426	200	100	66,8	33,4	16,7	6,68
4,27	2,135	1,067 5	0,427	199	99,7	66,5	33,2	16,6	6,65
4,28	2,140	1,070 0	0,428	198	99,2	66,2	33,1	16,5	6,62
4,29	2,145	1,072 5	0,429	198	98,8	65,8	32,9	16,5	6,58
4,30	2,150	1,075 0	0,430	197	98,3	65,5	32,8	16,4	6,55
4,31	2,155	1,077 5	0,431	196	97,8	65,2	32,6	16,3	6,52
4,32	2,160	1,080 0	0,432	195	97,3	64,9	32,4	16,2	6,49
4,33	2,165	1,082 5	0,433	194	96,8	64,6	32,3	16,1	6,46
4,34	2,170	1,085 0	0,434	193	96,4	64,2	32,1	16,1	6,42
4,35	2,175	1,087 5	0,435	192	95,9	63,9	32,0	16,0	6,39
4,36	2,180	1,090 0	0,436	191	95,4	63,6	31,8	15,9	6,36
4,37	2,185	1,092 5	0,437	190	95,0	63,3	31,7	15,8	6,33
4,38	2,190	1,095 0	0,438	189	94,5	63,0	31,5	15,8	6,30
4,39	2,195	1,097 5	0,439	188	94,1	62,7	31,4	15,7	6,27
4,40	2,200	1,100 0	0,440	187	93,6	62,4	31,2	15,6	6,24
4,41	2,205	1,102 5	0,441	186	93,2	62,1	31,1	15,5	6,21
4,42	2,210	1,105 0	0,442	185	92,7	61,8	30,9	15,5	6,18
4,43	2,215	1,107 5	0,443	185	92,3	61,5	30,8	15,4	6,15
4,44	2,220	1,110 0	0,444	184	91,8	61,2	30,6	15,3	6,12

Table C.1 (continued)

Ball indenter D mm				Force-diameter ratio $0,102 \times F/D^2$					
10	5	2,5	1	30	15	10	5	2,5	1
Mean diameter of the indentation d mm				Brinell hardness HBW					
4,45	2,225	1,1125	0,445	183	91,4	60,9	30,5	15,2	6,09
4,46	2,230	1,1150	0,446	182	91,0	60,6	30,3	15,2	6,06
4,47	2,235	1,1175	0,447	181	90,5	60,4	30,2	15,1	6,04
4,48	2,240	1,1200	0,448	180	90,1	60,1	30,0	15,0	6,01
4,49	2,245	1,1225	0,449	179	89,7	59,8	29,9	14,9	5,98
4,50	2,250	1,1250	0,450	179	89,3	59,5	29,8	14,9	5,95
4,51	2,255	1,1275	0,451	178	88,9	59,2	29,6	14,8	5,92
4,52	2,260	1,1300	0,452	177	88,4	59,0	29,5	14,7	5,90
4,53	2,265	1,1325	0,453	176	88,0	58,7	29,3	14,7	5,87
4,54	2,270	1,1350	0,454	175	87,6	58,4	29,2	14,6	5,84
4,55	2,275	1,1375	0,455	174	87,2	58,1	29,1	14,5	5,81
4,56	2,280	1,1400	0,456	174	86,8	57,9	28,9	14,5	5,79
4,57	2,285	1,1425	0,457	173	86,4	57,6	28,8	14,4	5,76
4,58	2,290	1,1450	0,458	172	86,0	57,3	28,7	14,3	5,73
4,59	2,295	1,1475	0,459	171	85,6	57,1	28,5	14,3	5,71
4,60	2,300	1,1500	0,460	170	85,2	56,8	28,4	14,2	5,68
4,61	2,305	1,1525	0,461	170	84,8	56,5	28,3	14,1	5,65
4,62	2,310	1,1550	0,462	169	84,4	56,3	28,1	14,1	5,63
4,63	2,315	1,1575	0,463	168	84,0	56,0	28,0	14,0	5,60
4,64	2,320	1,1600	0,464	167	83,6	55,8	27,9	13,9	5,58
4,65	2,325	1,1625	0,465	167	83,3	55,5	27,8	13,9	5,55
4,66	2,330	1,1650	0,466	166	82,9	55,3	27,6	13,8	5,53
4,67	2,335	1,1675	0,467	165	82,5	55,0	27,5	13,8	5,50
4,68	2,340	1,1700	0,468	164	82,1	54,8	27,4	13,7	5,48
4,69	2,345	1,1725	0,469	164	81,8	54,5	27,3	13,6	5,45
4,70	2,350	1,1750	0,470	163	81,4	54,3	27,1	13,6	5,43
4,71	2,355	1,1775	0,471	162	81,0	54,0	27,0	13,5	5,40
4,72	2,360	1,1800	0,472	161	80,7	53,8	26,9	13,4	5,38
4,73	2,365	1,1825	0,473	161	80,3	53,5	26,8	13,4	5,35
4,74	2,370	1,1850	0,474	160	79,9	53,3	26,6	13,3	5,33
4,75	2,375	1,1875	0,475	159	79,6	53,0	26,5	13,3	5,30
4,76	2,380	1,1900	0,476	158	79,2	52,8	26,4	13,2	5,28
4,77	2,385	1,1925	0,477	158	78,9	52,6	26,3	13,1	5,26
4,78	2,390	1,1950	0,478	157	78,5	52,3	26,2	13,1	5,23
4,79	2,395	1,1975	0,479	156	78,2	52,1	26,1	13,0	5,21
4,80	2,400	1,2000	0,480	156	77,8	51,9	25,9	13,0	5,19
4,81	2,405	1,2025	0,481	155	77,5	51,6	25,8	12,9	5,16
4,82	2,410	1,2050	0,482	154	77,1	51,4	25,7	12,9	5,14
4,83	2,415	1,2075	0,483	154	76,8	51,2	25,6	12,8	5,12
4,84	2,420	1,2100	0,484	153	76,4	51,0	25,5	12,7	5,10
4,85	2,425	1,2125	0,485	152	76,1	50,7	25,4	12,7	5,07
4,86	2,430	1,2150	0,486	152	75,8	50,5	25,3	12,6	5,05
4,87	2,435	1,2175	0,487	151	75,4	50,3	25,1	12,6	5,03
4,88	2,440	1,2200	0,488	150	75,1	50,1	25,0	12,5	5,01
4,89	2,445	1,2225	0,489	150	74,8	49,8	24,9	12,5	4,98
4,90	2,450	1,2250	0,490	149	74,4	49,6	24,8	12,4	4,96
4,91	2,455	1,2275	0,491	148	74,1	49,4	24,7	12,4	4,94
4,92	2,460	1,2300	0,492	148	73,8	49,2	24,6	12,3	4,92
4,93	2,465	1,2325	0,493	147	73,5	49,0	24,5	12,2	4,90
4,94	2,470	1,2350	0,494	146	73,2	48,8	24,4	12,2	4,88
4,95	2,475	1,2375	0,495	146	72,8	48,6	24,3	12,1	4,86
4,96	2,480	1,2400	0,496	145	72,5	48,3	24,2	12,1	4,83
4,97	2,485	1,2425	0,497	144	72,2	48,1	24,1	12,0	4,81
4,98	2,490	1,2450	0,498	144	71,9	47,9	24,0	12,0	4,79
4,99	2,495	1,2475	0,499	143	71,6	47,7	23,9	11,9	4,77
5,00	2,500	1,2500	0,500	143	71,3	47,5	23,8	11,9	4,75

Table C.1 (continued)

Ball indenter D mm				Force-diameter ratio $0,102 \times F/D^2$					
10	5	2,5	1	30	15	10	5	2,5	1
Mean diameter of the indentation: d mm				Brinell hardness HBW					
5,01	2,505	1,252 5	0,501	142	71,0	47,3	23,7	11,8	4,73
5,02	2,510	1,255 0	0,502	141	70,7	47,1	23,6	11,8	4,71
5,03	2,515	1,257 5	0,503	141	70,4	46,9	23,5	11,7	4,69
5,04	2,520	1,260 0	0,504	140	70,1	46,7	23,4	11,7	4,67
5,05	2,525	1,262 5	0,505	140	69,8	46,5	23,3	11,6	4,65
5,06	2,530	1,265 0	0,506	139	69,5	46,3	23,2	11,6	4,63
5,07	2,535	1,267 5	0,507	138	69,2	46,1	23,1	11,5	4,61
5,08	2,540	1,270 0	0,508	138	68,9	45,9	23,0	11,5	4,59
5,09	2,545	1,272 5	0,509	137	68,6	45,7	22,9	11,4	4,57
5,10	2,550	1,275 0	0,510	137	68,3	45,5	22,8	11,4	4,55
5,11	2,555	1,277 5	0,511	136	68,0	45,3	22,7	11,3	4,53
5,12	2,560	1,280 0	0,512	135	67,7	45,1	22,6	11,3	4,51
5,13	2,565	1,282 5	0,513	135	67,4	45,0	22,5	11,2	4,50
5,14	2,570	1,285 0	0,514	134	67,1	44,8	22,4	11,2	4,48
5,15	2,575	1,287 5	0,515	134	66,9	44,6	22,3	11,1	4,46
5,16	2,580	1,290 0	0,516	133	66,6	44,4	22,2	11,1	4,44
5,17	2,585	1,292 5	0,517	133	66,3	44,2	22,1	11,1	4,42
5,18	2,590	1,295 0	0,518	132	66,0	44,0	22,0	11,0	4,40
5,19	2,595	1,297 5	0,519	132	65,8	43,8	21,9	11,0	4,38
5,20	2,600	1,300 0	0,520	131	65,5	43,7	21,8	10,9	4,37
5,21	2,605	1,302 5	0,521	130	65,2	43,5	21,7	10,9	4,35
5,22	2,610	1,305 0	0,522	130	64,9	43,3	21,6	10,8	4,33
5,23	2,615	1,307 5	0,523	129	64,7	43,1	21,6	10,8	4,31
5,24	2,620	1,310 0	0,524	129	64,4	42,9	21,5	10,7	4,29
5,25	2,625	1,312 5	0,525	128	64,1	42,8	21,4	10,7	4,28
5,26	2,630	1,315 0	0,526	128	63,9	42,6	21,3	10,6	4,26
5,27	2,635	1,317 5	0,527	127	63,6	42,4	21,2	10,6	4,24
5,28	2,640	1,320 0	0,528	127	63,3	42,2	21,1	10,6	4,22
5,29	2,645	1,322 5	0,529	126	63,1	42,1	21,0	10,5	4,21
5,30	2,650	1,325 0	0,530	126	62,8	41,9	20,9	10,5	4,19
5,31	2,655	1,327 5	0,531	125	62,6	41,7	20,9	10,4	4,17
5,32	2,660	1,330 0	0,532	125	62,3	41,5	20,8	10,4	4,15
5,33	2,665	1,332 5	0,533	124	62,1	41,4	20,7	10,3	4,14
5,34	2,670	1,335 0	0,534	124	61,8	41,2	20,6	10,3	4,12
5,35	2,675	1,337 5	0,535	123	61,5	41,0	20,5	10,3	4,10
5,36	2,680	1,340 0	0,536	123	61,3	40,9	20,4	10,2	4,09
5,37	2,685	1,342 5	0,537	122	61,0	40,7	20,3	10,2	4,07
5,38	2,690	1,345 0	0,538	122	60,8	40,5	20,3	10,1	4,05
5,39	2,695	1,347 5	0,539	121	60,6	40,4	20,2	10,1	4,04
5,40	2,700	1,350 0	0,540	121	60,3	40,2	20,1	10,1	4,02
5,41	2,705	1,352 5	0,541	120	60,1	40,0	20,0	10,0	4,00
5,42	2,710	1,355 0	0,542	120	59,8	39,9	19,9	9,97	3,99
5,43	2,715	1,357 5	0,543	119	59,6	39,7	19,9	9,93	3,97
5,44	2,720	1,360 0	0,544	119	59,3	39,6	19,8	9,89	3,96
5,45	2,725	1,362 5	0,545	118	59,1	39,4	19,7	9,85	3,94
5,46	2,730	1,365 0	0,546	118	58,9	39,2	19,6	9,81	3,92
5,47	2,735	1,367 5	0,547	117	58,6	39,1	19,5	9,77	3,91
5,48	2,740	1,370 0	0,548	117	58,4	38,9	19,5	9,73	3,89
5,49	2,745	1,372 5	0,549	116	58,2	38,8	19,4	9,69	3,88
5,50	2,750	1,375 0	0,550	116	57,9	38,6	19,3	9,66	3,86
5,51	2,755	1,377 5	0,551	115	57,7	38,5	19,2	9,62	3,85
5,52	2,760	1,380 0	0,552	115	57,5	38,3	19,2	9,58	3,83
5,53	2,765	1,382 5	0,553	114	57,2	38,2	19,1	9,54	3,82
5,54	2,770	1,385 0	0,554	114	57,0	38,0	19,0	9,50	3,80
5,55	2,775	1,387 5	0,555	114	56,8	37,9	18,9	9,47	3,79
5,56	2,780	1,390 0	0,556	113	56,6	37,7	18,9	9,43	3,77

Table C.1 (concluded)

Ball indenter D mm				Force-diameter ratio $0,102 \times F/D^2$					
10	5	2,5	1	30	15	10	5	2,5	1
Mean diameter of the indentation d mm				Brinell hardness HBW					
5,57	2,785	1,392 5	0,557	113	56,3	37,6	18,8	9,39	3,76
5,58	2,790	1,395 0	0,558	112	56,1	37,4	18,7	9,35	3,74
5,59	2,795	1,397 5	0,559	112	55,9	37,3	18,6	9,32	3,73
5,60	2,800	1,400 0	0,560	111	55,7	37,1	18,6	9,28	3,71
5,61	2,805	1,402 5	0,561	111	55,5	37,0	18,5	9,24	3,70
5,62	2,810	1,405 0	0,562	110	55,2	36,8	18,4	9,21	3,68
5,63	2,815	1,407 5	0,563	110	55,0	36,7	18,3	9,17	3,67
5,64	2,820	1,410 0	0,564	110	54,8	36,5	18,3	9,14	3,65
5,65	2,825	1,412 5	0,565	109	54,6	36,4	18,2	9,10	3,64
5,66	2,830	1,415 0	0,566	109	54,4	36,3	18,1	9,06	3,63
5,67	2,835	1,417 5	0,567	108	54,2	36,1	18,1	9,03	3,61
5,68	2,840	1,420 0	0,568	108	54,0	36,0	18,0	8,99	3,60
5,69	2,845	1,422 5	0,569	107	53,7	35,8	17,9	8,96	3,58
5,70	2,850	1,425 0	0,570	107	53,5	35,7	17,8	8,92	3,57
5,71	2,855	1,427 5	0,571	107	53,3	35,6	17,8	8,89	3,56
5,72	2,860	1,430 0	0,572	106	53,1	35,4	17,7	8,85	3,54
5,73	2,865	1,432 5	0,573	106	52,9	35,3	17,6	8,82	3,53
5,74	2,870	1,435 0	0,574	105	52,7	35,1	17,6	8,79	3,51
5,75	2,875	1,437 5	0,575	105	52,5	35,0	17,5	8,75	3,50
5,76	2,880	1,440 0	0,576	105	52,3	34,9	17,4	8,72	3,49
5,77	2,885	1,442 5	0,577	104	52,1	34,7	17,4	8,68	3,47
5,78	2,890	1,445 0	0,578	104	51,9	34,6	17,3	8,65	3,46
5,79	2,895	1,447 5	0,579	103	51,7	34,5	17,2	8,62	3,45
5,80	2,900	1,450 0	0,580	103	51,5	34,3	17,2	8,59	3,43
5,81	2,905	1,452 5	0,581	103	51,3	34,2	17,1	8,55	3,42
5,82	2,910	1,455 0	0,582	102	51,1	34,1	17,0	8,52	3,41
5,83	2,915	1,457 5	0,583	102	50,9	33,9	17,0	8,49	3,39
5,84	2,920	1,460 0	0,584	101	50,7	33,8	16,9	8,45	3,38
5,85	2,925	1,462 5	0,585	101	50,5	33,7	16,8	8,42	3,37
5,86	2,930	1,465 0	0,586	101	50,3	33,6	16,8	8,39	3,36
5,87	2,935	1,467 5	0,587	100	50,2	33,4	16,7	8,36	3,34
5,88	2,940	1,470 0	0,588	99,9	50,0	33,3	16,7	8,33	3,33
5,89	2,945	1,472 5	0,589	99,5	49,8	33,2	16,6	8,30	3,32
5,90	2,950	1,475 0	0,590	99,2	49,6	33,1	16,5	8,26	3,31
5,91	2,955	1,477 5	0,591	98,8	49,4	32,9	16,5	8,23	3,29
5,92	2,960	1,480 0	0,592	98,4	49,2	32,8	16,4	8,20	3,28
5,93	2,965	1,482 5	0,593	98,0	49,0	32,7	16,3	8,17	3,27
5,94	2,970	1,485 0	0,594	97,7	48,8	32,6	16,3	8,14	3,26
5,95	2,975	1,487 5	0,595	97,3	48,7	32,4	16,2	8,11	3,24
5,96	2,980	1,490 0	0,596	96,9	48,5	32,3	16,2	8,08	3,23
5,97	2,985	1,492 5	0,597	96,6	48,3	32,2	16,1	8,05	3,22
5,98	2,990	1,495 0	0,598	96,2	48,1	32,1	16,0	8,02	3,21
5,99	2,995	1,497 5	0,599	95,9	47,9	32,0	16,0	7,99	3,20
6,00	3,000	1,500 0	0,600	95,5	47,7	31,8	15,9	7,96	3,18

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